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## CONTENTS

## INTRODUCTION

Concerns about the quality of finished water from the municipal water systems of Rosiclare and Elizabethtown were expressed by the Illinois governor's office and Mr. Dennis Stover of the Illinois Environmental Protection Agency (IEPA). The concern involved bacteria that were present in groundwater from both locations and "white material that appears" in the water of Rosiclare.

This report summarizes a preliminary investigation of these two municipal wells. The purpose of our investigation was to briefly examine the general geology of the study area, visit the Rosiclare and Elizabethtown areas, and collect and analyze water samples and available water quality data. A variety of techniques were used to determine the quality, the approximate age (time since recharge), and the geochemical evolution of the groundwater.

### Geology and Hydrology

The cities of Rosiclare and Elizabethtown are located in the karst region of the Shawnee Hills of southern Illinois in Hardin County (figs.1 and 2). The surficial bedrock near Rosiclare and Elizabethtown is Mississippian age, Valmeyeran rocks that include the limestones of the Ste. Genevieve, St. Louis, and Salem Formations, which commonly contain karst features (Panno et al., 1997). Bedrock is relatively flat-lying and exhibits only gentle dips. These rocks are fractured and faulted in the Rosiclare-Elizabethtown area in what Weller (1920) referred to as the Central Faulted Zone (fig. 3). This area has been referred to as ". . . the most complex and disturbed region in the state" (Weller et al., 1952). Mineralization within these fault zones and, to a lesser extent, fracture zones by fluorite and related minerals (calcite, quartz, sphalerite, galena, pyrite, chalcopyrite, and barite) constitutes the ore deposits of this area (Weller, 1920; Weller et al., 1952). Calcite typically fills the fractures and faults of the limestone of the St. Louis and Ste. Genevieve Formations (Weller, 1920) and effectively seals much of the secondary porosity. However, the faults and fractures at some locations in this region are coincident with surface springs and appear to provide the conduits necessary for groundwater circulation (Weller, 1920).

The Mississippian age rocks are overlain by thin loess soil that is less than 3 meters thick (Lineback, 1979). Sinkholes are common in the study area; they appear as circular to elliptical, bowl-shaped depressions in the soil. Sinkholes form as a result of soil collapsing into cavities in the underlying carbonate rock. Because limestone is relatively soluble, fractures within the bedrock are readily enlarged by infiltrating rainwater and soil water. This water also infiltrates and flows along bedding planes and is responsible for the formation of caves in the area (fig. 2). Groundwater in karst regions is especially vulnerable to surface-borne contaminants because of the direct connection of surface water to the aquifer. Recharging water plunges down sinkholes and into the shallow karst aquifer, leaving little time for filtration or chemical and biological degradation of surface-borne contaminants (White, 1988).

Groundwater in the study area is pumped from the Mississippian age limestones for use as private and public water supplies (Pryor, 1956). Groundwater present within the fractures, bedding planes, and, to a lesser extent, within the rock itself is tapped by the municipal wells for the cities of Rosiclare and Elizabethtown (Appendix A). The two towns switched from using Ohio River water in 1993 as a result of stricter mandates for the treatment of surface water for municipal use (Dennis Stover, IEPA, personal communication, 2000). To date, there has been no source water

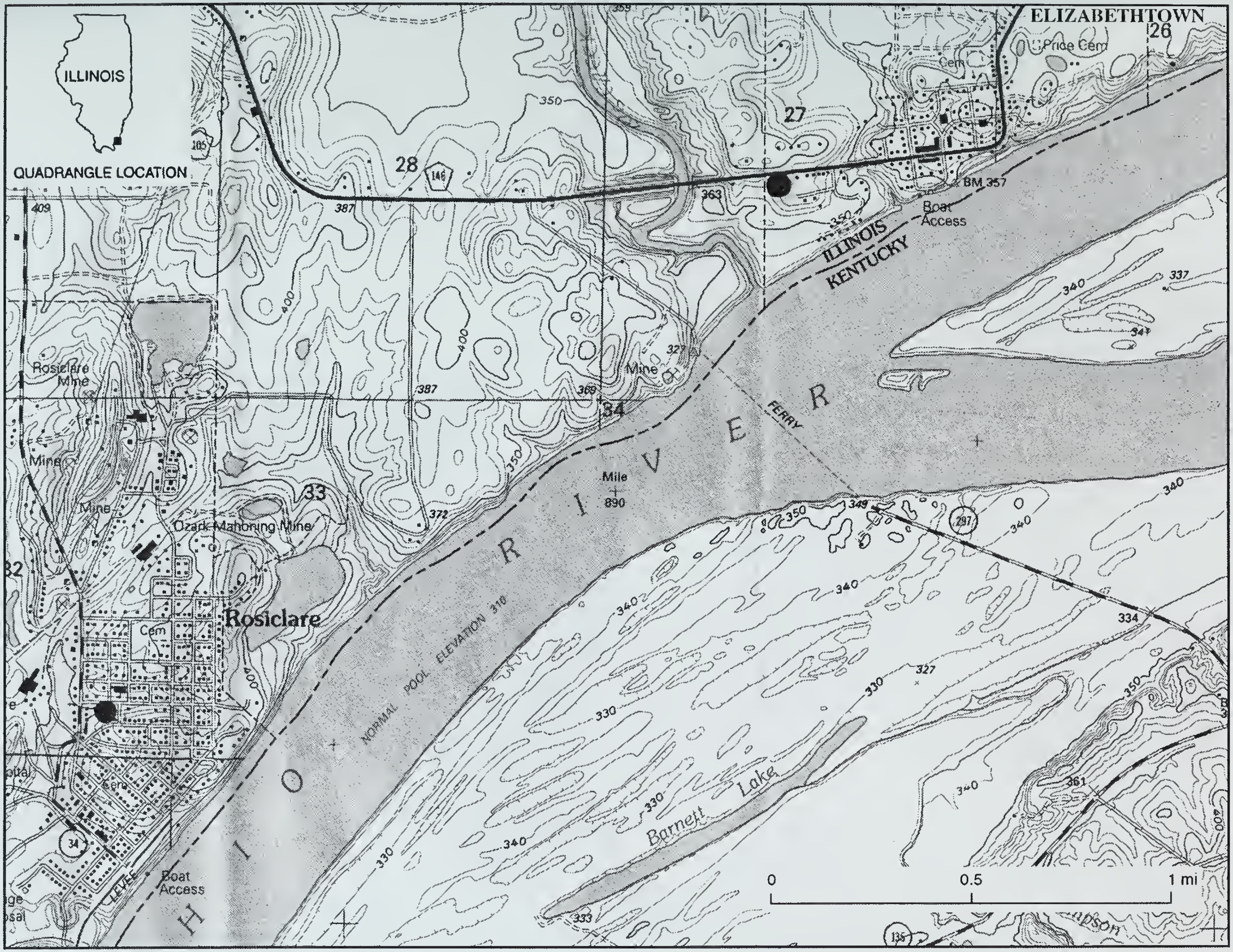


**Figure 1.** Location map of the towns of Rosiclare and Elizabethtown, Illinois, and their municipal well fields as seen on a U.S. Geological Survey 7.5-minute quadrangle map. Wells in each town are marked with large black circles. Contour interval is 10 feet (3.05 meters).

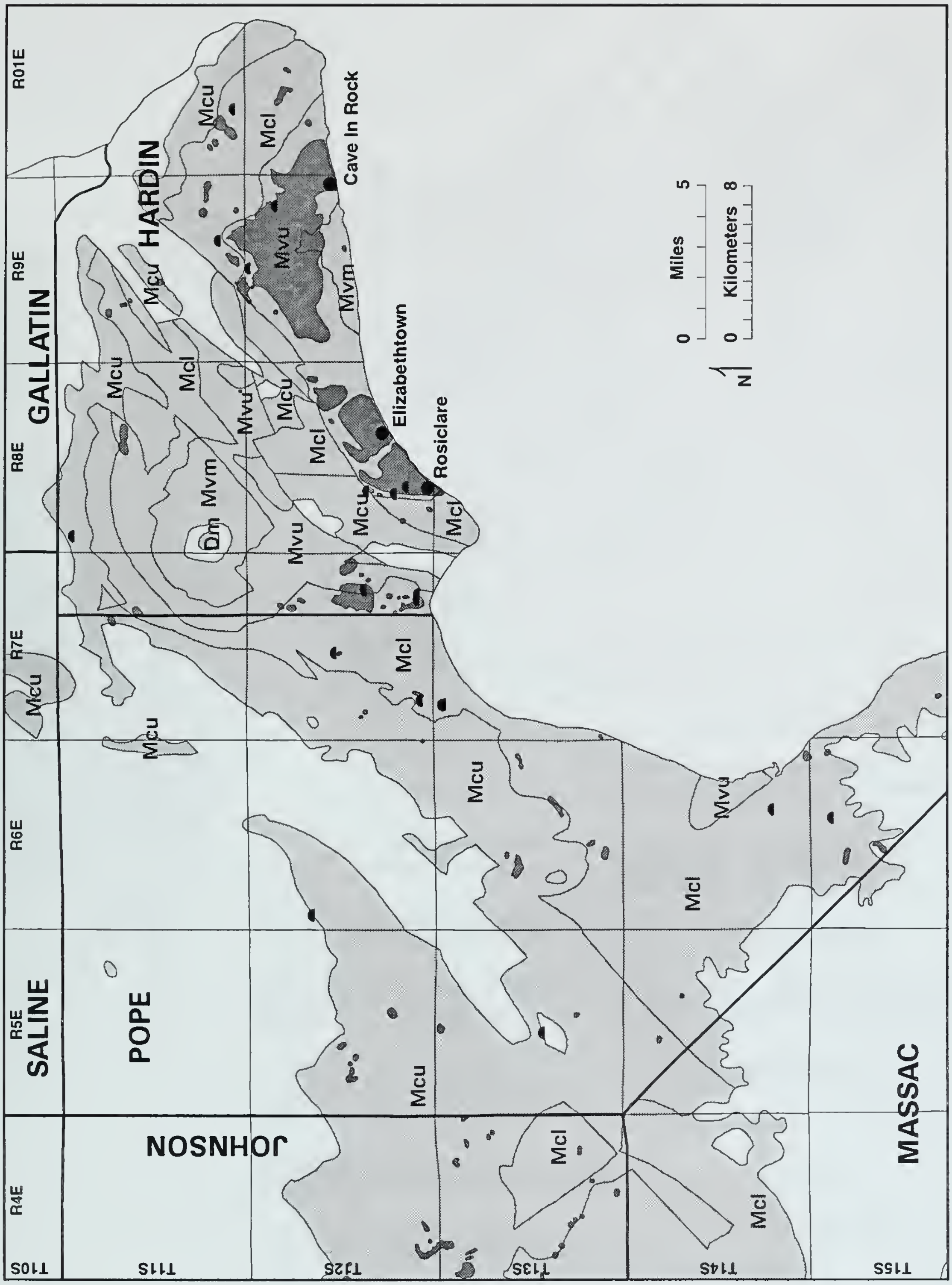


**Figure 2.** Karst map of the eastern part of the Shawnee Hills karst region of southern Illinois. The white and light gray areas indicate land surface underlain by noncarbonate rock and carbonate rock, respectively. The dark gray areas indicate karst terrain, and the black half circles represent the locations of known caves. Mcl = Mississippian, middle Valmeyeran; Mcu = Mississippian, upper Valmeyeran; Dm = middle Devonian. Modified from Panno et al. (1997).

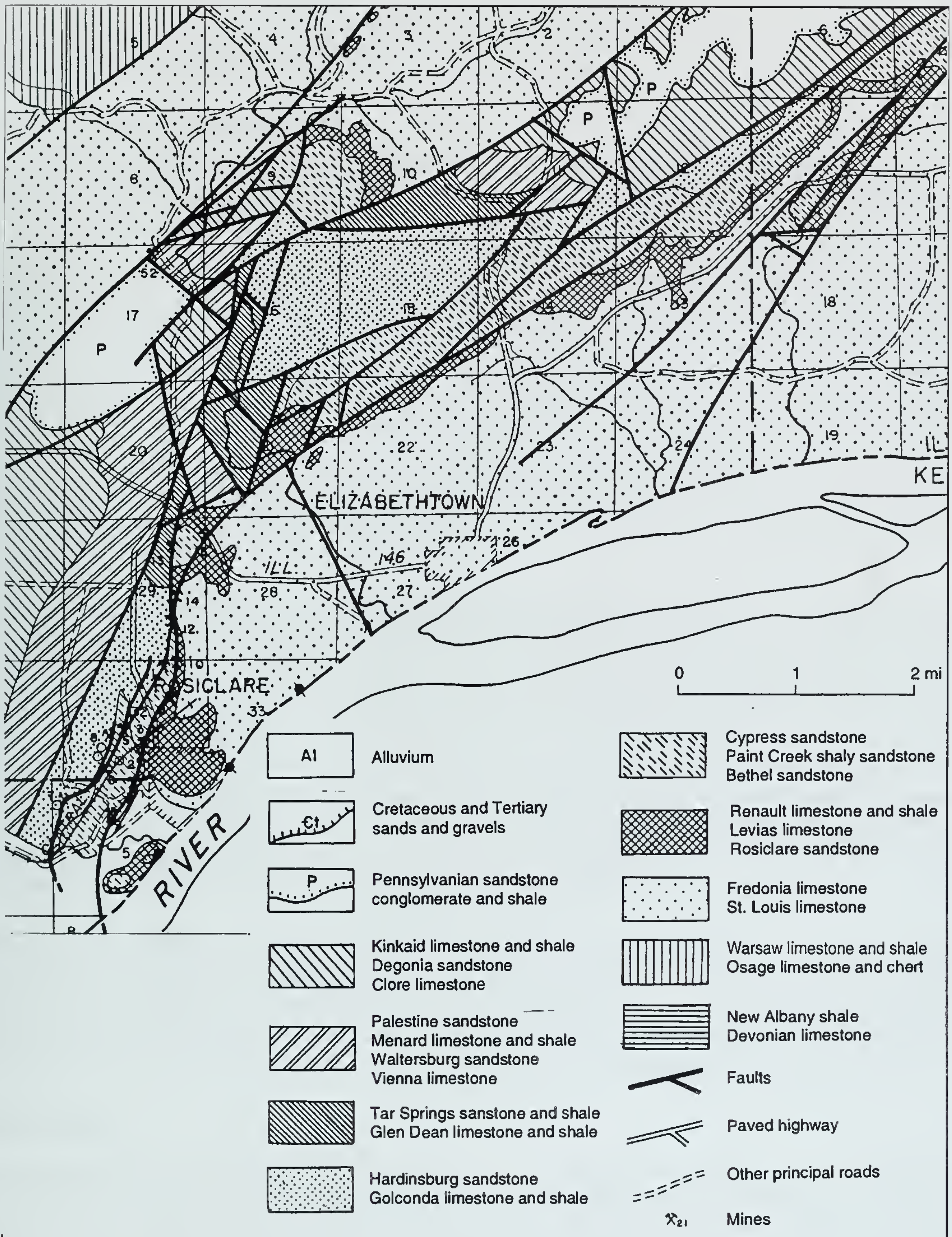


**Figure 3.** Map of Hardin County showing the location of the Central Faulted Zone relative to Rosiclare and Elizabethtown (modified from Weller et al., 1952).

ment, nor has a wellhead protection plan been developed for either community (Wade Boring, IEPA, personal communication, 2000).

### Recharge and Groundwater Flow

A cursory examination of the groundwater hydrology of the Rosiclare-Elizabethtown area was conducted, and some generalizations about recharge and groundwater flow were made based on the geology and stratigraphy of the area. The stratigraphy of the area, as reflected in the well logs from the test holes in Rosiclare, is dominated by limestone (Appendix A). Panno et al. (1997) showed that the upper Valmeyeran Limestone subcrops in this area and is the formation in the state most susceptible to karstification. Consequently, the area contains numerous sinkholes that result from solutionally widened crevices and bedding planes. Groundwater recharge in karst areas typically includes the flow of surface water runoff from rainfall and snowmelt into sinkholes and through macropores in the thin soils. Water that enters a sinkhole flows directly into crevices and conduits that make up the karst aquifer. Groundwater flow is primarily through karst features in the limestone (caves, smaller conduits, bedding planes, solution-enlarged fractures). Because of the relatively large conduits connecting surface water with groundwater, recharge in karst terrain is extremely rapid. Regional groundwater flow is typically toward large stream valleys (in this case, the Ohio River).

Faulty well construction can also allow contaminated shallow groundwater to mix with cleaner, deeper groundwater. Panno et al. (1996) showed that the vertical stratification of contaminants in the shallow karst aquifer of southwestern Illinois and questionable well construction practices (casing through the soil zone and only about 1 meter into bedrock) contributed to the mixing of shallow groundwater with deeper groundwater sources. Chronic well construction problems in Rosiclare's well field led the water plant manager to speculate that the casing of the wells is relatively shallow (7 to 8 meters) and/or poorly grouted (well construction records cannot be found). During the original drilling of well no. 2, the driller and water plant manager observed that shallow groundwater seeped into the borehole at about 12 meters below the surface (N. Culby, Rosiclare Water Plant Manager, personal communication, 2000).

Finally, the possibility exists that the Ohio River could contribute additional recharge to the municipal wells. Continued pumping of the wells in close proximity to the Ohio River and flooding of the river during the spring has the potential to locally reverse the hydraulic gradient and draw river water into the fracture-dominated aquifer. Because of the implications of this type of recharge to water quality, the possibility of such recharge was investigated and is discussed.

## METHODS

Two groundwater samples were collected on March 13, 2000; one sample was collected from the Rosiclare municipal well no. 2, and the other was collected from one of the Elizabethtown municipal wells. Elizabethtown has two wells, but the groundwater from one well has a strong hydrogen sulfide odor and has never been used (Dennis Stover, IEPA, personal communication, 1999).

Both water samples were analyzed for cations, anions, atrazine, bacteria, and tritium. Samples collected for cations and anions were filtered through 0.45-μm membranes and stored in 30- and

60-mL polyethylene bottles, respectively. Samples to be analyzed for cations were acidified in the field with ultrapure nitric acid to a pH of 2.0. Samples to be analyzed for atrazine were collected in 1-L glass bottles that had been rinsed in methanol and oven-dried for 24 hours at 80°C. Samples to be analyzed for bacterial content were collected in sterile 100-mL plastic bottles, and tritium samples were collected in clean, dry 1-L Nalgene high-density polyethylene bottles. All samples were transported in ice-filled coolers to the laboratory and kept refrigerated at approximately 4°C until analyses were completed.

Concentrations of cations in water samples were determined with a Thermo-Jarrell Ash Model ICAP 61e Inductively Coupled Argon Plasma Spectrometer. Instrument operation, interelement interference correction, background correction, and data collection were controlled using Thermo-SPEC/AE 6.20 software. Blanks, calibration check standards, and reference standards were run with each sample set. Solution concentrations of anions were determined using a Dionex 211i ion chromatograph with Ionpac AG14 Guard Column, Ionpack AS14 Analytical Column, and Anion Self-Regenerating Suppressor-11 (4 mm) following the U.S. Environmental Protection Agency (USEPA) Method 300.0 (Pfaff, 1993). Analytes were measured with a CDM-3 conductivity detector cell with a DS4 detection stabilizer. The eluent was 3.5 m*M* sodium carbonate and 1.0 m*M* sodium bicarbonate. Instrument operations and data collection were controlled using Peak-Net 5.01 software. A calibration check standard and blank were run with each sample set.

Water chemistry data were evaluated with the chemical reaction model NETPATH (Plummer et al., 1994) to determine the saturation state and charge imbalance of the water samples. The charge imbalance for both samples was about 5%, which was within acceptable limits.

Groundwater samples were analyzed for bacteria and atrazine by the Illinois Department of Agriculture's Animal Disease Laboratory, Centralia, Illinois. Prior to sample collection, the sampling port was flamed with a propane torch for up to 10 seconds to destroy any bacteria or pesticides that might have contaminated the port. Bacterial samples were collected in two sterile 120-mL bottles and analyzed within 24 hours of collection for total coliforms, fecal coliforms, and total (other) bacteria using standard methods to isolate and identify bacterial colonies (Clesceri et al., 1989). Bacterial species were identified and listed from most to least dominant. Samples were analyzed for atrazine using gas chromatography and mass spectrometry techniques (USEPA, 1988).

Tritium analyses were conducted using the electrolytic enrichment process (Ostlund and Dorsey, 1977) and liquid scintillation counting. The electrolytic enrichment process consists of distillation, electrolysis, and purification of enriched water samples. The results of the tritium analyses are reported in tritium units (TU). One TU is defined as 1 tritium atom per $10^{18}$ hydrogen atoms. The precision for the tritium analyses reported in this study is 0.25 TU.

Finally, data collected weekly by the Rosiclare Water Plant (pH, specific conductance, and temperature) from the Ohio River and well no. 2 (Appendix B) were plotted against time of sample collection. These results were examined and compared with our samples.

## RESULTS AND DISCUSSION

### Groundwater Chemistry

The groundwater samples from Rosiclare and Elizabethtown are rich in calcium bicarbonate, which is typical of groundwater from karst terrain (Table 1). However, both samples were undersaturated with respect to calcite and dolomite and oversaturated with respect to quartz. White (1988) stated that "most karst waters are not in equilibrium with solid calcite or dolomite." The relatively low saturation indices for calcite in these wells suggests that they are part of the karst system and are receiving an influx of more dilute water (e.g., rainwater and snowmelt and/or river water). Oversaturation with respect to quartz suggests that the groundwater is in intimate contact with silicate minerals such as quartz and feldspars. This oversaturation also suggests that there may be mixing in the aquifer with groundwater from sandstone units just to the north.

**Fluoride and Strontium** The Rosiclare sample is unusually high in fluoride and strontium with concentrations of 1.46 and 1.34 mg/L, respectively. Fluoride and strontium concentrations in groundwater are typically less than 1 mg/L (Hem, 1985) and do not exceed 0.35 and 0.23 mg/L, respectively, in spring water samples from the southwestern Illinois sinkhole plain (Panno et al., 2000). The concentration of fluoride in the Rosiclare water sample is relatively high and exceeds the Illinois Department of Public Health's recommended fluoride level for drinking water of 0.9 to 1.2 mg/L (IDPH, 1999). Fluoride does not exceed the USEPA's regulatory limit of 4 mg/L for drinking water (USEPA, 1999). The elevated concentration of fluoride is undoubtedly derived from fluorite mineralization present in the carbonate rocks near Rosiclare. The source of strontium is not known, but may be related to fluorite mineralization as a substitute for calcium in fluorite ($CaF_2$). There is no regulatory limit for strontium. Compared with groundwater from Rosiclare, fluoride and strontium concentrations in groundwater from Elizabethtown are considerably lower at 0.20 and 0.38 mg/L, respectively, and more typical of groundwater in unmineralized carbonate rock.

**Redox Conditions** Redox conditions in groundwater reflect the water's degree of isolation from the atmosphere and its interactions with a soil zone and an underlying aquifer. Groundwater that is in contact with the atmosphere or surface water that recently entered bedrock (e.g., through a sinkhole within the last few days) is typically oxidizing (contains an oxidant such as oxygen or nitrate). Groundwater that has been removed from the atmosphere for weeks or months may be under reducing conditions (contains a reductant such as dissolved organic matter) (Appelo and Postma, 1994). The redox conditions within an aquifer affect the character and concentration of metals dissolved in groundwater.

Groundwater flowing from the Rosiclare well had a hydrogen sulfide odor, suggesting reducing conditions. This suggestion is supported by its relatively low oxygen potential (Eh) values, and high iron and manganese concentrations (Table 1). The Elizabethtown groundwater had no such odor, and iron and manganese concentrations were below detection limits (Table 1). The Eh value for the Elizabethtown groundwater was only slightly lower than those found in karst springs in southwestern Illinois (Panno et al., 2000) and is characteristic of a more open groundwater system.

**Table 1.** The chemical composition of groundwater collected from the municipal wells at Rosiclare and Elizabethtown, Illinois. All data are reported as milligrams per liter unless otherwise indicated.

| | Rosiclare | Elizabethtown |
|---|---|---|
| Date | 13 March 00 | 13 March 00 |
| Temperature, °C | 16 | 16 |
| pH | 6.8 | 6.8 |
| Eh,[1] mV | 137 | 312 |
| Specific conductance, µS/cm | 694 | 695 |
| Alkalinity (as $CaCO_3$) | 316 | 326 |
| Na | 27.4 | 11.7 |
| K | <2 | <2 |
| Ca | 109 | 13 |
| Mg | 20.5 | 17.6 |
| Sr | 1.34 | 0.38 |
| Ba | 0.172 | 0.038 |
| $SiO_2$ | 14.8 | 22.1 |
| $HCO_3$ | 385 | 397 |
| $SO_4$ | 25.3 | 20.3 |
| Cl | 25.1 | 15.4 |
| Br | 0.02 | 0.02 |
| F | 1.46 | 0.2 |
| $NO_3$ | 0.09 | 4.77 |
| Fe | 1.65 | 0.01 |
| Mn | 0.76 | 0.01 |
| TA,[2] cfu/100 mL | 600 | 850 |
| TC, cfu/100 mL | 3 | 4 |
| FC, cfu/100 mL | 0 | 0 |
| FE, cfu/100 mL | 4 | 0 |
| Tritium, TU | 4.14 | 4.50 |

[1]Oxidation potential.

[2]TA, total aerobic; TC, total coliforms; FC, fecal coliforms; FE, fecal enterococcus; cfu/mL, colony-forming units per 100 mL of water; TU, tritium units.

**Nitrate** Nitrate was found in the Elizabethtown well sample at a concentration of 4.77 mg of N/L. This concentration, which is well above the background level identified by Panno et al. (1996) of 1.4 mg of N/L for karst groundwater in southwestern Illinois, suggests the input of agrichemicals and/or livestock or human waste. Nitrate in the Rosiclare well sample was relatively low, at least in part because of the relatively strong reducing conditions. Ammonia was not determined for either sample.

**pH and Specific Conductance** Data collected by the Rosiclare Water Plant revealed a seasonality to the groundwater quality of the water from well no. 2 collected from April 1997 to April 1998 (figs. 4 and 5). Both pH and specific conductance, which are typically controlled by the interaction of water with the carbonate bedrock (e.g., Panno et al., 1996), show seasonal fluctuations. The pH dips from about 7.8 for most of the year to about 7.2 during late winter and early spring,

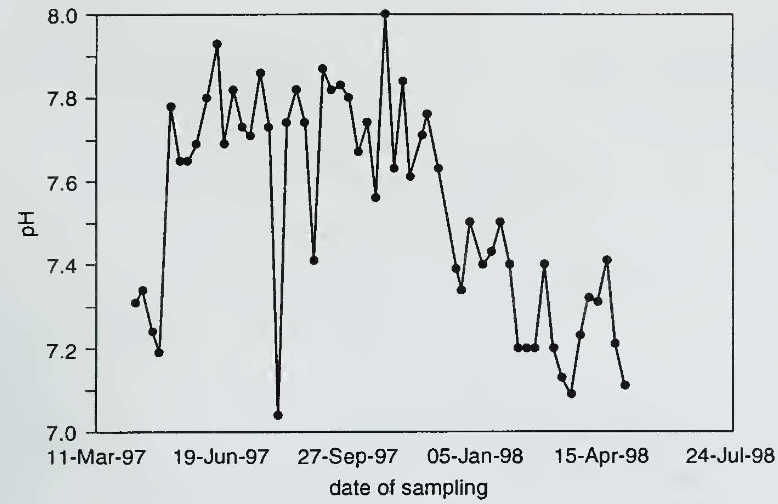


**Figure 4.** The change in pH versus time (from April 1997 to April 1998) for groundwater from Rosiclare's well no. 2. Data provided by the Rosiclare Water Plant. The pH greatly increases in early spring and decreases steadily until the next spring, suggesting seasonal variability.

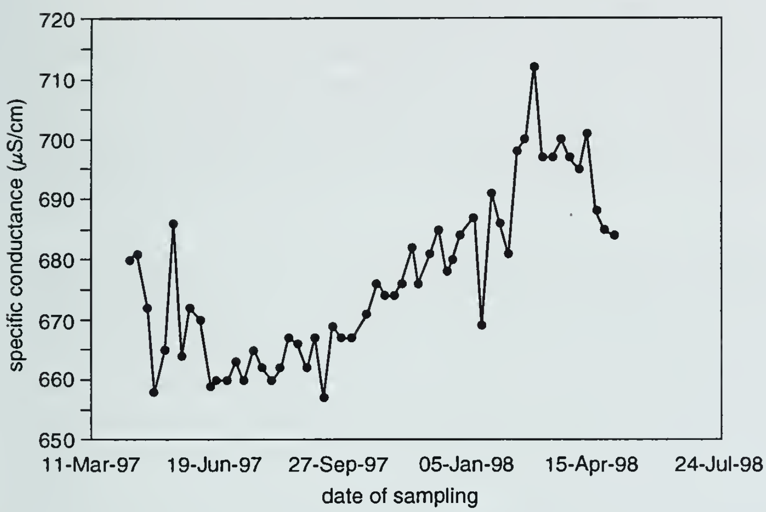


**Figure 5.** The change in specific conductance versus time (from April 1997 to April 1998) for groundwater from Rosiclare's well no. 2. Data are provided by the Rosiclare Water Plant. The specific conductance decreases in spring, followed by a steady increase until the beginning of the next spring.

whereas the specific conductance, a measure of the electrical conductivity of the water that is controlled by alkalinity in karst regions, decreases in spring to about 660 μS/cm and slowly increases with time until the following winter to about 700 μS/cm. Normally, rainwater and snowmelt infiltrate into an aquifer as part of the aquifer recharge process. The addition of fresh water is usually responsible for changes in water quality and chemical composition; that is, the mixing of fresh water with groundwater in equilibrium with its host rock results in a dilution of the groundwater and a reduction in the specific conductance and pH. This result is because surface water, derived from precipitation, has a very low specific conductance (typically 2 μS/cm) and a relatively low pH of approximately 4.4 in this area (National Atmospheric Deposition Program, 1998). This type of relationship appears to be reflected by the specific conductance of the Rosiclare groundwater. However, the behavior of the pH over time is contrary to what would be expected with a simple recharge model, which suggests that the controls on the pH of groundwater flowing to well no. 2 are complex and cannot be delineated using our limited data.

**Infiltration of River Water** The possibility that water from the Ohio River is being drawn into the Rosiclare well field was investigated using water quality data collected by the Rosiclare Water Plant. Mechanisms for mixing river water with groundwater of the karst aquifer that lies

upgradient of the river are well known. A karst aquifer typically has little storage capacity (they are dominated by fracture porosity); thus, removal of water from a karst aquifer has the potential to create a relatively extensive cone of depression. Flooding conditions in the spring and continuous pumping of the wells could allow the cone of depression to intersect the river (which lies about 0.5 kilometer from the town wells) and reverse the hydraulic gradient. Consequently, river water could be drawn into the wells as a mixture of regional groundwater flowing from the northwest and water from surface recharge. The relatively high pH (7.7 to 8.9) and low specific conductance (300 to 500 μS/cm) of the river water (Appendix B) conceivably could explain the seasonality of the groundwater from Rosiclare's well no. 2.

However, a comparison of the available data on pH and specific conductance of groundwater from Rosiclare's well no. 2 and river water, sampled over the course of one year, revealed that this latter hypothesis is unlikely (figs. 6 and 7). Mixing curves were calculated using samples from well water and river water collected from March through April (fig. 6) and August through November (fig. 7) as end members. Different percentages of each end member water, when mixed with each other, follow a well-defined mixing curve. The data from the Rosiclare well and the river (figs. 6 and 7) tended to follow their own trends and did not interact. Consequently, it is doubtful that river water is having any effect on the quality of Rosiclare's well water. Because no such data were available for Elizabethtown's well, the potential for the influx of river water there is unknown.

**Tritium** Tritium concentrations in both groundwater samples were 4.1 and 4.5 TU and represent recent precipitation. For comparison, tritium ranges from 2.42 to 7.73 TU in rainwater and snow melt from southwestern Illinois. Tritium in water samples from relatively large springs in southwestern Illinois ranged from 3.93 to 7.79 TU (K.C. Hackley, Illinois State Geological Survey, unpublished data). Because tritium has a half-life of 12.43 years (Clark and Fritz, 1997), the age of the groundwater from both wells is considered modern. Extrapolating back using tritium's half-life, using only radioactive decay, the groundwater from both wells could have fallen as rain or snow any time within the last 15 years. However, considering the karst terrain and the similarity of the tritium concentration observed in these groundwater samples to that in recent precipitation in southern Illinois, it is possible that these groundwater samples represent precipitation that fell within the last year or so. Additional analyses would have to be done to more accurately determine the age of the groundwater.

**Bacteria** Bacteria present in the water samples from both wells included aerobic, coliform, and fecal enterococcus bacteria (Table 2). It is possible that the *Bacillus* and *Pseudomonas* species were introduced into the well during drilling operations. These species are ubiquitous in the springs of southwestern Illinois (Panno et al., 1999). *Klebsiella pneumoniae* is an environmental coliform that is commonly associated with decaying wood and that also could have been introduced into the well with soil during drilling. The Rosiclare sample contained *Enterococcus faecium,* a fecal bacteria associated with animal waste. This bacterium is relatively short-lived outside of its host (Kaddu-Mulindwa et al., 1983), so its presence strongly suggests an active connection with surface water, such as infiltration of surface recharge and/or mixing of river water. These results agree with the tritium data and support the interpretation that the groundwater samples are of very recent origin.

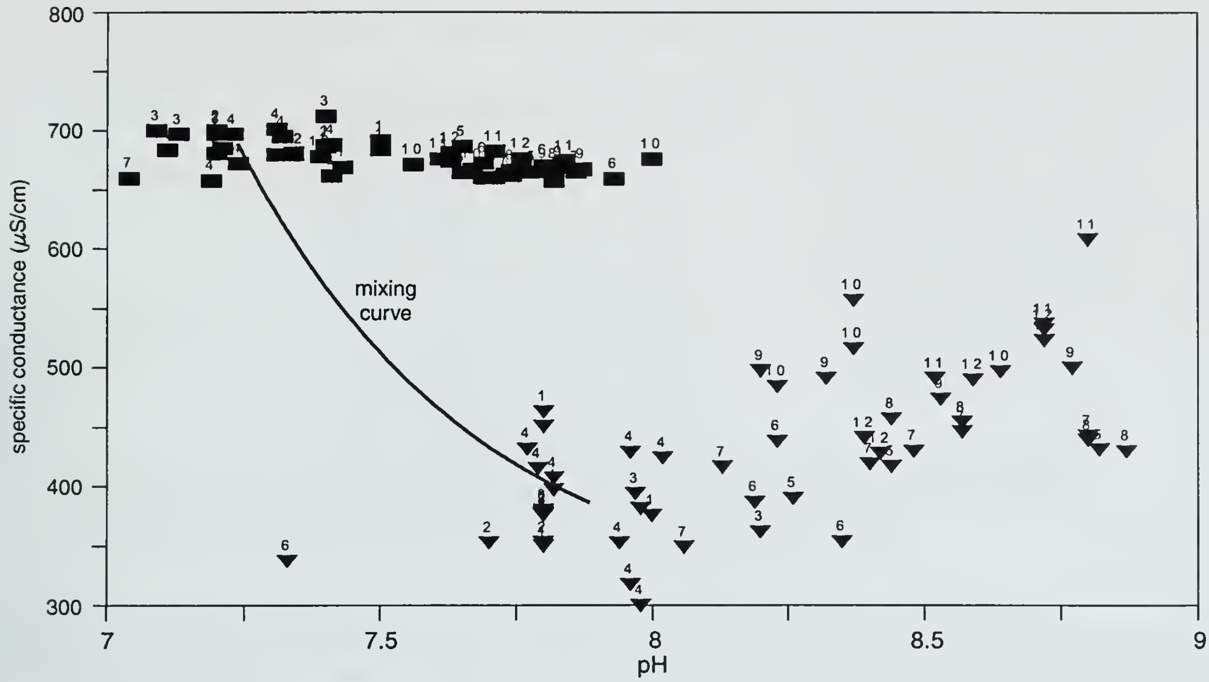


**Figure 6.** Water quality data from Rosiclare well no. 2 (squares) and the Ohio River (triangles) for one year showing that the distribution of pH and specific conductance form two separate populations. A mixing curve for March and April waters (a continuous mixing of the two waters in various proportions) does not indicate any degree of mixing between the two waters. The numbers above the symbols refer to the month the sample was collected (e.g., 1 = January).

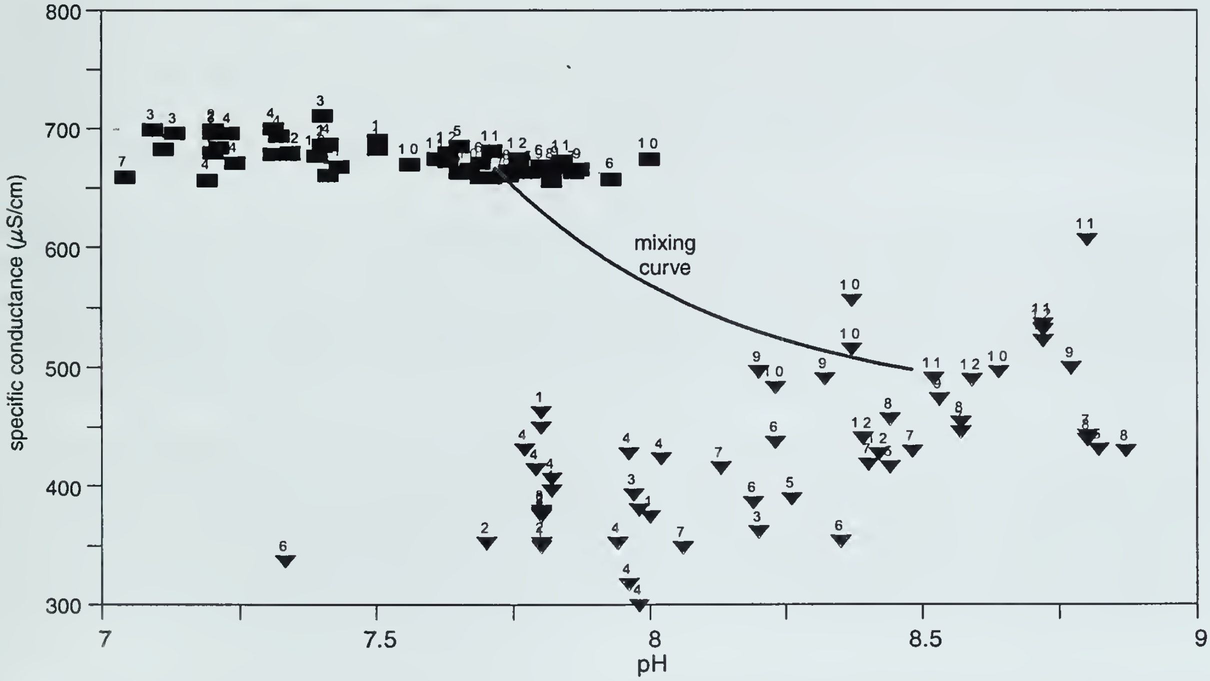


**Figure 7.** Water quality data from Rosiclare well no. 2 (squares) and Ohio River (triangles) for one year showing that the distribution of pH and specific conductance form two separate populations. A mixing curve for August through November waters does not indicate any degree of mixing between the two waters.

**Table 2.** Bacterial species isolated from water samples collected from the Rosiclare and Elizabethtown wells.

| City well | Bacterial indicators[1] | (cfu/mL) | Bacterial species[2] |
|---|---|---|---|
| Rosiclare | Total aerobic | 600 | *Bacillus* spp. |
| | Total coliforms | 3 | *Pseudomonas* spp. |
| | Fecal coliforms | 0 | *Klebsiella pneumoniae* |
| | Fecal enterococcus | 4 | *Enterococcus faecium* |
| Elizabethtown | Total aerobic | 850 | *Pseudomonas* spp. |
| | Total coliforms | 4 | *Bacillus* spp. |
| | Fecal coliforms | 0 | *Enterobacter aerogenes* |
| | Fecal enteroococcus | 0 | |

[1]Bacterial indicators are measured in colony-forming units (cfu) per 100 mL of water.

[2]Bacterial species are listed in order of most abundant to least abundant.

Panno et al. (1996) found that bacterial contamination was seasonal in the karst landscape of southwestern Illinois. Coliform bacteria were found in 55% of the wells during the summer, but only in 21 to 28% of the wells during other seasons. It is possible that water samples collected during the summer in the Rosiclare and Elizabethtown areas might also contain elevated concentrations of bacteria.

**Pesticides** Because of the ubiquitous nature of atrazine in the Midwest, this pesticide is an excellent indicator of surface-derived contamination in agricultural areas. Atrazine is typically found in springs and wells in the karst landscape of southwestern Illinois. However, positive detections of atrazine in that area are typically seasonal in nature; that is, atrazine is most commonly detected in the spring, following its application (Panno et al., 1996). Although the Rosiclare wells were located in town, probably at least 1 kilometer from the nearest corn field, the Elizabethtown well was in close proximity to corn fields and other agricultural activities.

The results of our sampling showed that no atrazine was found in either well; the detection limit is 0.2 part per billion (0.0002 mg/L). Our water samples were collected in March, and atrazine was not applied to the fields until the following months. Because of the seasonal nature of atrazine in karst groundwater (Panno et al., 1996), the best time to sample the wells would be the weeks following the first significant rainfall event after application of agrichemicals to fields near the wells.

**White Precipitate** The white material observed in the water by residents was also observed by the authors while boiling water at Cave-in-Rock (fig. 2) and was determined to be calcium carbonate. Heating water that is near saturation with respect to calcite results in the precipitation of calcium carbonate caused by the retrograde solubility of the mineral (the solubility of calcite decreases with an increase in heat) and evaporation. The precipitate is a function of the hardness of the water and does not pose a threat to consumers.

Although water samples collected from Rosiclare and Elizabethtown were undersaturated with respect to calcite, this saturation may vary depending on the time of year. As shown in the data from

Rosiclare well no. 2 (figs. 4 and 5), the pH and specific conductivity changed significantly throughout the year. The highest pH values (between pH 7.7 and 7.9) suggest water that is probably at or near calcite saturation from late spring to midwinter.

## SUMMARY AND RECOMMENDATIONS

Potential problems with water quality involving the positive detection of bacteria and the appearance of a white precipitate in the water from the municipal wells of the southern Illinois towns of Rosiclare and Elizabethtown prompted our initial investigation into their sources of groundwater. The towns lie within the karst region of the Shawnee Hills, and soil thickness in the area is typically 3 meters or less.

Groundwater in the area is pumped from deep wells that are open to carbonate bedrock and produce a hard, calcium bicarbonate type of water. Water samples collected in March were, surprisingly, undersaturated with respect to calcite. The concentration of nitrate in the groundwater of Elizabethtown was relatively high at 4.77 mg/L, suggesting contamination from surface sources (e.g., agrichemicals). Rosiclare's groundwater had little nitrate (0.09 mg/L), which is consistent with its strong reducing condition. Bacteria were present in both groundwater samples, suggesting the presence of surface-derived animal wastes. Tritium values suggest that groundwater from both wells was surface water as young as 15 years before present, but other evidence suggests the water could be as recent as the last year or two. A more recent recharge age is supported by the bacterial data and the seasonal fluctuations in pH and the specific conductance of the groundwater. The most likely sources of nitrate, bacteria, and tritium are surface recharge through karst features.

Although only two water samples were collected, we can make some generalizations and recommendations for future work. Groundwater from both wells appears to be receiving relatively recent water from surface recharge. In karst terrain such as this, surface recharge is through sinkholes and macropores in the thin soils. Poor well construction practices (not casing deeply enough to avoid input from the shallow karst aquifer and/or improper casing installation) can allow surface-borne contaminants to seep into the well and contaminate otherwise good-quality groundwater. Finally, river water could possibly flow into the wells via fractures in the aquifer during spring flooding events and with continuous pumping of the wells. However, mixing curves—using well water and river water as end members—do not support this possibility for Rosiclare's well. No such data were available from Elizabethtown's well.

Because of the rapid recharge through karst features to the groundwater in the bedrock, seasonal effects on groundwater pumped by the wells are not only possible but also likely. Our samples were collected in late winter to early spring and are by no means representative of samples collected throughout the year. That is, elevated concentrations of nitrate, pesticides, and bacteria could enter the wells at both Rosiclare and Elizabethtown at other times during the year. Specifically, nitrate and pesticide concentrations are likely to be relatively high in spring, and bacterial concentrations are likely to be relatively high in late spring and summer. Wells that are not going to be renovated should be analyzed four times (seasonally) for a full year for cations, anions (including nitrate), field parameters, ammonia, pesticides, bacteria, and tritium. This seasonal analysis would

provide a representative suite of samples that could be used to evaluate fully the degree of contamination present in the wells.

The municipality of Rosiclare is currently discussing plans to renovate its wells so that the casing provides protection from groundwater entering from the contaminated shallow karst aquifer. We recommended that these actions be taken as soon as possible to prevent input from the shallow groundwater that is apparently contaminated. Although it was not possible to get information on the construction of the Elizabethtown well, it is likely that the well has similar well casing problems; we suggested that the city consider similar actions. In addition, because of the very rapid recharge generally afforded by the karst terrain, if evidence of surface water contamination continues after renovation of the wells, we would recommend that recharge zones for the wells be delineated and a wellhead protection plan be put in place for those wells.

## ACKNOWLEDGMENTS

We thank Mr. Dennis Stover of the Illinois Environmental Protection Agency for his assistance in collecting historic information on the Rosiclare and Elizabethtown wells. We thank Dr. Edward Mehnert of the Illinois State Geological Survey and Mr. Stover for their review of this report.

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APPENDIX A

Test Well Logs
Rosiclare Water Plant

**G & L WELL SERVICE**

ROUTE 2 BOX 22
DONGOLA, ILLINOIS 62926
Ph. 618-827-4722

SEPTEMBER 24 1991

CITY OF ROSICLARE
ROSICLARE,IL 62982

STARTED 9-13-91
FINISHED 9-21-91

TEST WELL # 1

0' - 10' DIRT AND CLAY.
10' - 16' YELLOW SANDSTONE AND CLAY.
16' - 72' GRAY LIMESTONE.
72' - 123' LIGHT GRAY FOSSLY LIMESTONE.
123' - 4 GPM.
123' - 161' DARK GRAY LIMESTONE.
161' - 497' LIGHT GRAY FOSSLY LIMESTONE AND GRAY LIMESTONE.
497' - 4 gpm.
497' - 517' DARK GRAY LIMESTONE.
517' - 52 GPM.
517' - 570' DARK GRAY LIMESTONE.
570' - 610' GRAY LIMESTONE.
610' - 700' DARK GRAY AND BLACKISH GRAY LIMESTONE.

63 FOOT OF 6 " STEEL WELL CASING.
100 GALLON PER MINUTE FLOW.
STATIC LEVEL 45 FOOT.

G& L WELL SERVICE
Leonard R. Beanland
LEONARD R. BEANLAND

**G & L WELL SERVICE**

ROUTE 2 BOX 22
DONGOLA, ILLINOIS 62926
Ph. 618-827-4722

SEPTEMBER 26,1991

CITY OF ROSICLARE
ROSICLARE,IL 62982

STARTED 9-21-91
FINISHED 9-24-91

TEST WELL # 2

0 - 4' DIRT AND CLAY.
4'-8' YELLOW SAND AND CLAY.
8' - 18' YELLOW CLAY.
18' - 41' GRAY LIMESTONE.
41' - 47' DARK GRAY LIMESTON WITH STREAKS OF SHALE.
47' - 61' DARK LIMESTONE.
61' 121' LIGHT GRAY FOSSLY LIMESTONE.
121' - BREAK ( 20 ) G P M .
121' - 283' DARK GRAY LIMESTONE.
283' - BREAK ( 35) G P M .
283' - 390' LIGHT GRAY FOSSLY LIMESTONE.
390' - 513' DARK GRAY LIMESTONE.
513' - BREAK ( 32 ) G P M .
513' - 520' DARK GRAY LIMESTONE.

G & L WELL SERVICE
Leonard R Beanland
LEONARD R. BEANLAND

# APPENDIX B

## Water Quality Data
## Rosiclare Water Plant

Rosiclare Water Plant
Facility #0690150

| Time: | Date: 4-10-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 8:40 | Lab Tests River | 58 | 7.82 | 397 | .97 | 11°c | <0.04 |
| 8:30 | Lab Tests Well #2 | 1.3 | 7.31 | 680 | .71 | 15°c | 0.32 |

| Time: | Date: 4-16-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 12:35 | Lab Tests River | 26 | 7.79 | 415 | .37 | 12°c | <0.04 |
| 12:50 | Lab Tests Well #2 | 1.0 | 7.34 | 681 | .76 | 14°c | 0.37 |

| Time: | Date: 4-24-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 8:50 | Lab Tests River | 19 | 7.96 | 429 | .30 | 12°c | 0.18 |
| 8:55 | Lab Tests Well #2 | 1.2 | 7.24 | 672 | .55 | 14°c | 0.37 |

| Time: | Date: 4-29-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1:45 | Lab Tests River | 25 | 7.77 | 432 | .48 | 16°c | 0.04 |
| 1:50 | Lab Tests Well #2 | 2.9 | 7.19 | 658 | .51 | 14°c | 0.27 |

| Time: | Date: 5-8-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 10:20 | Lab Tests River | 26 | 8.26 | 390 | .33 | 17°c | <0.04 |
| 10:15 | Lab Tests Well #2 | 2.3 | 7.78 | 665 | .53 | 15°c | 0.32 |

| Time: | Date: 5-15-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1:15 | Lab Tests River | 35 | 8.44 | 417 | .42 | 17°c | 0.04 |
| 1:10 | Lab Tests Well #2 | 1.5 | 7.65 | 686 | .71 | 15°c | 0.32 |

Rosiclare Water Plant
Facility #0690150

| Time: | Date: 5-21-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 10:15 | Lab Tests River | 27 | 8.82 | 431 | .51 | 18°c | 0.04 |
| 10:20 | Lab Tests Well #2 | 1.8 | 7.65 | 664 | .29 | 14°c | 0.32 |

| Time: | Date: 5-28-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1:50 | Lab Tests River | 17 | 8.23 | 438 | .29 | 19°c | <0.04 |
| 2:00 | Lab Tests Well #2 | .19 | 7.69 | 672 | .67 | 15°c | 0.27 |

| Time: | Date: 6-5-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1:20 | Lab Tests River | 59 | 8.35 | 354 | .76 | 18°c | <0.04 |
| 1:15 | Lab Tests Well #2 | 1.4 | 7.80 | 670 | .36 | 14°c | 0.42 |

| Time: | Date: 6-13-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 8:00 | Lab Tests River | 35 | ~~7.39~~ | 338 | .48 | 20°c | <0.04 |
| 8:10 | Lab Tests Well #2 | 2.9 | 7.93 | 659 | .17 | 16°c | 0.42 |

| Time: | Date: 6-18-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 10:40 | Lab Tests River | 40 | 8.19 | 387 | 0.55 | 21°c | <0.04 |
| 10:50 | Lab Tests Well #2 | 1.9 | 7.69 | 660 | 0.40 | 15°c | 0.46 |

| Time: | Date: 6-26-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1:40 | Lab Tests River | 45 | 8.06 | 349 | 0.99 | 24°c | <0.04 |
| 1:55 | Lab Tests Well #2 | 1.5 | 7.82 | 660 | 0.43 | 14°c | 0.42 |

Rosiclare Water Plant
Facility #0690150

| Time: | Date: 7-3-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1030 | Lab Tests River | 17 | 8.13 | 416 | 0.11 | 26°c | <0.04 |
| 1040 | Lab Tests Well #2 | 1.8 | 7.73 | 663 | 0.42 | 15°c | 0.37 |

| Time: | Date: 7-9-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1:00 | Lab Tests River | 15 | 8.40 | 419 | 0.26 | 27°c | 0.04 |
| 1:20 | Lab Tests Well #2 | 1.7 | 7.71 | 660 | 0.62 | 15°c | 0.37 |

| Time: | Date: 7-17-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1:20 | Lab Tests River | 6.2 | 8.57 | 446 | 0.08 | 30°c | <0.04 |
| 1:25 | Lab Tests Well #2 | 1.3 | 7.86 | 664 | 0.37 | 15°c | 1.04 |

| Time: | Date: 7-24-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 9:05 | Lab Tests River | 8.0 | 8.48 | 430 | 0.16 | 28°c | <0.04 |
| 9:15 | Lab Tests Well #2 | 2.7 | 7.73 | 662 | 0.64 | 14°c | 0.51 |

| Time: | Date: 7-31-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 12:55 | Lab Tests River | 12 | 8.80 | 443 | 0.05 | 28°c | <0.04 |
| 1:00 | Lab Tests Well #2 | 1.1 | 7.04 | 660 | 0.45 | 14°c | 0.32 |

| Time: | Date: 8-7-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 9:00 | Lab Tests River | 4.7 | 8.87 | 430 | 0.03 | 26°c | <0.04 |
| 9:10 | Lab Tests Well #2 | 1.1 | 7.74 | 662 | 0.40 | 14°c | 0.37 |

Rosiclare Water Plant
Facility #0690150

| Time: | Date: 8-14-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1:30 | Lab Tests River | 3.0 | 8.57 | 454 | 0.04 | 27°c | <0.04 |
| 1:40 | Lab Tests Well #2 | 1.2 | 7.82 | 667 | 0.33 | 16°c | 0.32 |

| Time: | Date: 8-21-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 10:00 | Lab Tests River | 9.5 | 8.44 | 457 | 0.13 | 25°c | <0.04 |
| 10:10 | Lab Tests Well #2 | 1.5 | 7.74 | 666 | 0.40 | 15°c | 0.32 |

| Time: | Date: 8-28-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 9:10 | Lab Tests River | 5.5 | 8.80 | 459 | 0.13 | 26.8°c | <0.04 |
| 9:20 | Lab Tests Well #2 | 1.2 | 7.41 | 662 | 0.53 | 15.8°c | 1.04 |

New Thermo

| Time: | Date: 9-4-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 10:20 | Lab Tests River | 6.0 | 8.77 | 500 | 0.12 | 27°c | <0.04 |
| 10:30 | Lab Tests Well #2 | 1.1 | 7.87 | 667 | 0.58 | 15°c | 0.72 |

| Time: | Date: 9-11-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1:05 | Lab Tests River | 4.5 | 8.20 | 497 | 0.06 | 26.2°c | <0.04 |
| 1:15 | Lab Tests Well #2 | 1.5 | 7.82 | 657 | 0.49 | 15.6°c | 0.37 |

| Time: | Date: 9-18-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| | Lab Tests River | 7.7 | 8.53 | 474 | 0.06 | 25.3°c | <0.04 |
| | Lab Tests Well #2 | .89 | 7.93 | 669 | 0.51 | 15.7°c | 0.46 |

Rosiclare Water Plant
Facility #0690150

| ime: | Date: 9-25-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 25 | Lab Tests River | 3.7 | 8.32 | 491 | 0.06 | 27°c | <0.04 |
| .30 | Lab Tests Well #2 | 1.4 | 7.80 | 667 | 0.32 | 15°c | 0.56 |

| ime: | Date: 10-2-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| :05 | Lab Tests River | 3.7 | 8.64 | 497 | 0.14 | 21.9°c | <0.04 |
| :15 | Lab Tests Well #2 | .77 | 7.67 | 667 | 0.51 | 15.5°c | 0.56 |

| ime: | Date: 10-9-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| :35 | Lab Tests River | 2.9 | 8.23 | 484 | 0.04 | 22.4°c | <0.04 |
| :50 | Lab Tests Well #2 | 1.7 | 7.74 | | | 15.7°c | |

sample of well didn't get to — lab

| ime: | Date: 10-16-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 15 | Lab Tests River | 3.1 | 8.37 | 516 | 0.02 | 20.5°c | <0.04 |
| 25 | Lab Tests Well #2 | 1.7 | 7.56 | 671 | 0.49 | 15.6°c | 0.56 |
| :27 | → well #2 | 1.7 | 7.56 | 683 | 0.39 | 15.6°c | 0.56 |

| ime: | Date: 10-23-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| :00 | Lab Tests River | 1.5 | 8.37 | 557 | 0.04 | 18.3°c | <0.04 |
| :10 | Lab Tests Well #2 | 1.0 | 8.0 | 676 | 0.51 | 16.4°c | 0.56 |

got extra well #2 for last week

| ime: | Date: 10-30-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| :45 | Lab Tests River | 1.4 | 8.72 | 537 | 0.02 | 15.6°c | <0.04 |
| 11:00 | Lab Tests Well #2 | .86 | 7.63 | 674 | 0.40 | 15.8°c | 0.37 |

Rosiclare Water Plant
Facility #0690150

| Time: | Date: 11-6-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 10:30 | Lab Tests River | 5.0 | 8.52 | 491 | 0.12 | 13.0°c | <0.04 |
| 10:40 | Lab Tests Well #2 | 1.0 | 7.84 | 674 | 0.51 | 15.7°c | 0.32 |

| Time: | Date: 11-12-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 10:05 | Lab Tests River | 3.4 | 8.72 | 523 | 0.04 | 10.9°c | <0.04 |
| 10:20 | Lab Tests Well #2 | 1.5 | 7.61 | 676 | 0.53 | 15.6°c | 0.46 |

| Time: | Date: 11-20-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 10:25 | Lab Tests River | 3.6 | 8.80 | 608 | 0.07 | 10.1°c | <0.04 |
| 10:35 | Lab Tests Well #2 | .86 | 7.71 | 682 | 0.55 | 15.6°c | 0.46 |

| Time: | Date: 11-25-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1:40 | Lab Tests River | 2.6 | 8.72 | 532 | 0.04 | 10.4°c | <0.04 |
| 1:50 | Lab Tests Well #2 | 1.3 | 7.76 | 676 | 0.60 | 15.6°c | 0.56 |

| Time: | Date: 12-4-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 1:00 | Lab Tests River | 2.3 | 8.59 | 490 | 0.11 | 9.4°c | <0.04 |
| 1:10 | Lab Tests Well #2 | 1.1 | 7.63 | 681 | 0.53 | 15.6°c | 0.51 |

| Time: | Date: 12-11-97 | Turb | ~~P.H.~~ | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 10:00 | Lab Tests River | 6.1 | ~~8.08~~ | 424 | 0.15 | 12°c | <0.04 |
| 10:10 | Lab Tests Well #2 | 1.3 | ~~7.32~~ | 685 | 0.53 | 15.6°c | 0.23 |

P.H. Meter Not Work Right

Rosiclare Water Plant
Facility #0690150

| ne: | Date: 12-18-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 00 | Lab Tests River | 3.2 | 8.42 | 428 | 0.15 | 10.9 | <0.04 |
| 15 | Lab Tests Well #2 | 1.0 | 7.39 | 678 | 0.62 | 15.4 | 0.37 |

| ne: | Date: 12-22-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 40 | Lab Tests River | 3.5 | 8.39 | 441 | 0.11 | 9.9 | <0.04 |
| 30 | Lab Tests Well #2 | 1.5 | 7.34 | 680 | 0.51 | 16.3 | 0.61 |

| ne: | Date: 12-29-97 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 15 | Lab Tests River | 3.0 | 7.8 | 450 | 0.15 | 10.1 | <0.04 |
| 25 | Lab Tests Well #2 | 1.9 | 7.5 | 684 | 0.78 | 15.4 | 0.32 |

| ne: | Date: 1-8-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 55 | Lab Tests River | 94 | 7.8 | 463 | 0.17 | 9.9 | <0.04 |
| 40 | Lab Tests Well #2 | 1.9 | 7.4 | 687 | 1.47 | 15.5 | 0.46 |

| ne: | Date: 1-15-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| :10 | Lab Tests River | 73 | 7.80 | 350 | 1.8 | 10.2 | <0.04 |
| :00 | Lab Tests Well #2 | 5.0 | 7.43 | 669 | 2.2 | 16 | 0.67 |

Iron Flakes
Well Not Flushed Good

| me: | Date: 1-22-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| :30 | Lab Tests River | 65 | 8.0 | 375 | 1.5 | 6.3 | <0.04 |
| :40 | Lab Tests Well #2 | 1.9 | 7.5 | 691 | 0.99 | 15.6 | 0.72 |

Rosiclare Water Plant
Facility #0690150

| Time: | Date: 1-29-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 12:45 | Lab Tests River | 25 | 7.7 | 353 | 0.87 | 7.3°c | <0.04 |
| 12:55 | Lab Tests Well #2 | 2.5 | 7.4 | 686 | 1.08 | 15.5°c | 0.37 |

| Time: | Date: 2-5-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 9:55 | Lab Tests River | 7.2 | 7.8 | 377 | 0.22 | 5.8°c | <0.04 |
| 10:05 | Lab Tests Well #2 | 1.2 | 7.2 | 681 | 0.65 | 15.5°c | 0.42 |

| Time: | Date: 2-12-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 12:40 | Lab Tests River | 15 | 7.8 | 378 | 0.51 | 5.9°c | <0.04 |
| 12:55 | Lab Tests Well #2 | 1.5 | 7.2 | 698 | 5.5 | 15.5°c | 0.88 |

| Time: | Date: 2-18-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 10:00 | Lab Tests River | 37 | 7.8 | 353 | 0.80 | 6.1°c | <0.04 |
| 10.10 | Lab Tests Well #2 | 1.4 | 7.2 | 700 | 0.65 | 15.5°c | 0.37 |

| Time: | Date: 2-26-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 9:15 | Lab Tests River | 29 | 7.8 | 376 | 0.55 | 6.8°c | <0.04 |
| 9:40 | Lab Tests Well #2 | 2.7 | 7.4 | 712 | 0.71 | 15.6°c | 0.46 |

| Time: | Date: 3-5-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 9:45 | Lab Tests River | 40 | 7.8 | 380 | 1.02 | 6.9°c | <0.04 |
| 9:55 | Lab Tests Well #2 | 1.40 | 7.2 | 697 | 0.80 | 15.5°c | 0.46 |

# APPENDIX B *(continued)*

## Water Quality Data
## Rosiclare Water Plant

Rosiclare Water Plant
Facility #0690150

| Time: | Date: 3-12-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 9:55 | Lab Tests River | 26 | 8.20 | 362 | 0.49 | 7.3°c | <0.04 |
| 10:10 | Lab Tests Well #2 | 1.3 | 7.13 | 697 | 0.97 | 15.7°c | 0.61 |

| Time: | Date: 3-19-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 10:10 | Lab Tests River | 31 | 7.97 | 394 | 0.55 | 7.9°c | <0.04 |
| 10:20 | Lab Tests Well #2 | 2.3 | 7.09 | 700 | 1.08 | 15.8°c | 0.51 |

| Time: | Date: 3-26-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 8:45 | Lab Tests River | 47 | 7.94 | 353 | 1.31 | 9.8°c | <0.04 |
| 9:40 | Lab Tests Well #2 | 1.2 | 7.23 | 697 | 1.17 | 15.7°c | 0.46 |

| Time: | Date: 4-2-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 3:15pm | Lab Tests River | 56 | 7.82 | 407 | 1.11 | 17.6°c | <0.04 |
| 3:20pm | Lab Tests Well #2 | 1.6 | 7.32 | 695 | 0.58 | 16.5°c | 0.46 |

| Time: | Date: 4-9-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 8:30 | Lab Tests River | 45 | 8.02 | 424 | 0.65 | 14.2 | <0.04 |
| 8:25 | Lab Tests Well #2 | 15 | 7.31 | 701 | 1.20 | 16.1 | 0.56 |

Iron visible

| Time: | Date: 4-16-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| | Lab Tests River | 30 | 7.98 | 381 | 0.46 | 16.2 | <0.04 |
| | Lab Tests Well #2 | 4.1 | 7.41 | 688 | 1.56 | 16.9 | 0.51 |

Rosiclare Water Plant
Facility #0690150

| Time: | Date: 4-23-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 8:10 | Lab Tests River | 63 | 7.98 | 300 | 1.09 | 14.9°c | <0.04 |
| 8:25 | Lab Tests Well #2 | 1.3 | 7.21 | 685 | 1.17 | 15.8°C | 0.46 |

| Time: | Date: 4-30-98 | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| 7:55 | Lab Tests River | 17 | 7.96 | 318 | 0.40 | 14.7 | <0.04 |
| 8:10 | Lab Tests Well #2 | 1.1 | 7.11 | 684 | 0.39 | 15.9 | 0.32 |

| Time: | Date: | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| | Lab Tests River | | | | | | |
| | Lab Tests Well #2 | | | | | | |

| Time: | Date: | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| | Lab Tests River | | | | | | |
| | Lab Tests Well #2 | | | | | | |

| Time: | Date: | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| | Lab Tests River | | | | | | |
| | Lab Tests Well #2 | | | | | | |

| Time: | Date: | Turb | P.H. | Cond. | FE | Temp. | Mg. |
|---|---|---|---|---|---|---|---|
| | Lab Tests River | | | | | | |
| | Lab Tests Well #2 | | | | | | |